

FINAL REPORT

Landscape Evolution, A Comparison of Form and Process

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Project Goals

The grant was funded to support work to collect, analyze and interpret 3-dimensional physiographic data for understanding the processes responsible for landscape modification. The primary landforms to be studied were Neogene cinder cones in Arizona (San Francisco Volcanic Field (SFVF), Coconino and Kaibab National Forests, Arizona). We also obtained and are still analyzing digital topographic data for the Long Valley-White Mountains area of California, which display Quaternary normal fault scarps, as well as extensive evidence of degradation. (These are TOPSAR data that we are working on in conjunction with Dr. F. Webb of JPL.) The work resulted in a large database of measured rates of downslope transport of slope debris. It was hypothesized that the work would increase our understanding of process-response models of hillslope degradation, and of the effects of climate change and other parameters on degradation rates.

In greater detail, our primary goal was to compare evolutionary sequences of hillslopes, as exemplified by the topography of landforms of the same type but of different ages, with measurements of the surficial processes active on the landforms. Assuming that other parameters, such as hillslope materials and vegetation are held constant, and that the effects of changing climate are negligible, then the sediment transport rates measured today on the landforms should be the same as those calculated from the inversion of landform topography by use of a diffusion-type model. However, if the effects of changing climate or other factors are not negligible, then the observed transport rates would differ from those which must be invoked to explain the current topography. We hypothesized in fact that because degradation on the event scale is highly transient and localized, we would find a wide divergence between modern, measured transport rates, and rates calculated by global landform inversion or modeling.

Because of the length of time involved in collection of sufficient data on current degradation rates, we are still continuing to analyse and interpret the data. Completion of the work will increase our understanding of the potential effects of anthropogenic climate and surficial change on the Earth's solid surface, and possibly allow us to constrain paths of hillslope evolution following anthropogenic modifications, as well as compare the short-term with the long-term rates of hillslope degradation.

Work Accomplished

- *Fieldwork.* Preliminary reconnaissance work (1996) suggested that cinder cones fall into two major morphological categories, breached and unbreached. Breached cinder cones

are those from which cinder was rafted during formation to create a significant channel, resulting in a horseshoe shape in planform view.

It was decided to concentrate field efforts on the SFVF based on reconnaissance work both in the laboratory and in the field. The criteria used in this decision were the following: number of dated landforms, accessibility and the wide age range of cones. The cinder cones chosen for detailed study of event and annual degradation rates were the following: 1) Wild Bill Hill (350,000 yr B.P.) as an example of a cone of "middle" age, breached and heavily channelized; and 2) the Walker Lake cone (2.1 m.y. B.P.) as an example of an "old" cone, unbreached and relatively unchannelized. Detailed field mapping (Blauvelt, 1998) was also carried out at: 1) SP Mountain ($\sim 10^5$ yr B.P.), 2) Saddle Mountain (17000 yr B.P.), 3) Hills 4613 and 4614 (~ 0.5 m.y. B.P.), and 3) Walker Hill (3 m.y. B.P.). These mapping studies were undertaken to characterize as completely as possible the range of phenomena and landform modifications possible on hills of a wide range of ages and microclimates.

Throughout the term of the project, it was critical to collect field data pertaining to active slope process rates. These data were and are being collected on the two cones set aside for detailed study: Wild Bill Hill and Walker Lake cone. As stated in annual reports, we believe that a large fraction of hillslope degradation in the SFVF occurs directly after fires, which are analogs of the anthropogenic changes that are occurring over extensive portions of the forested globe (deforestation; Martinez-Batori et al., 1998; Martinez-Hackert et al., 1999; Martinez-Hackert and Bursik, 1999). Thus, it is highly likely that one result of human induced global change will be landform degradation rates higher than the long-term average. A Ph.D. student (B. Martinez-Hackert (formerly Batori) is currently engaged in analyzing downslope movement rates from rainsplash and overland flow; Blauvelt (1998) also carefully mapped the target scoria cones.

Our fieldwork on a catastrophic degradational event in Yosemite Valley (the Happy Isles rockfall) was also partially supported by this research, as a 'bonus' when we were driving through the valley on return from fieldwork in SFVF (Wieczorek et al., 2000).

- *Weather and Climate.* The extreme seasonality, variation in rainfall intensity, and their importance in the SFVF have led us to undertake a detailed characterization of rainfall patterns in this region. We have worked with Victor Passeti, NEXRAD Officer, and Steve Keighton, Sciences and Operations Officer and the Science Information Officer at the National Weather Service office in Bellemont, AZ, to characterize the rainfall patterns in the SFVF. Now that NEXRAD imagery is widely available on the web, we have begun maintaining NEXRAD rainfall estimates for days of interest in the SFVF. We also heavily instrumented the cinder cones with rain gauges: we now have three or more on both Wild Bill Hill and Walker Lake cone collecting data at any one time, including gauges that have digital data loggers attached. We are using the results of this research to characterize the size and intensity of rainfall cells that cause most of the landform degradation in the area (Martinez-Hackert and Bursik, 1999). We still envisage using these characterizations as input or constraints on cellular automaton-based modeling of the erosional process.

- *Modeling.* Diffusion type models of cinder cone degradation have already been developed and tested for obtaining global degradation rates of scoria cones (Hooper, 1997; see also Hooper and Sheridan, 1998, *Jour. Volcanol. Geotherm. Res.*, 83, 241-267). Current effort is focused on developing cellular automaton models of landform change. One version

of such a model that is based on the smoothed particle hydrodynamics solution method coupled with the cellular automaton method has already been completed and the results submitted to the open literature (Bursik et al., 1998). This model is a channel inception and diffusion routing model that was used in its first incarnation to model the propagation of debris flows at Popocatepetl volcano, Mexico. Not only are debris-flood waves simulated in a reasonable fashion, but erosion and deposition patterns are calculated, as well as the changes to the initial DEM that result from the movement of sediment.

Master's student M. Tischer completed laboratory studies of grain flows that are important degradational processes in the early history of cinder cones (Tischer, 1997; Tischer et al., 1998). Grain flows are particularly prominent at SP Crater, but also are obvious over parts of Wild Bill Hill. The work of Tischer has allowed us to obtain an extremely thorough understanding of scoria cone degradation from the earliest to some of the latest stages.

- *Digital Data.* Digital topographic data were obtained in all four field seasons using a total station geodimeter over small regions of approximately 10^3 to 10^4 m². These data take advantage of an innovative technique that we have developed for this project of measuring millimeter-level erosion remotely, and may be adaptable to aircraft platforms. We have obtained complete coverage for the area from USGS DEMs, and investigated the acquisition of ERS-1 data, which did not prove useful. We have also obtained a digital DEM of the Long Valley Caldera area, California, formed from TOPSAR data, upon which we have been applying our CA/SPH modeling and diffusion modeling, as normal fault scarps, as well as a variety of volcanic landforms, including cinder cones, appear in the scene obtained, and show excellent evidence for degradation (Hooper et al., 1998; 2000 in prep.).

- *Human Resources Development.* One post-doctoral researcher (D. Hooper, as per the original proposal), and one Ph.D. student (B. Martinez-Hackert) were funded to pursue work related to the project. Hooper concentrated on DEMs and modeling (Hooper et al., 1997, 1998; 2000 in prep.), Martinez-Battori on event-data collection and modeling (Martinez-Battori et al., 1998; 1999). Two M.S. students (Tischer, 1997; Blauvelt, 1998) have already completed M.S. theses on topics related to the work, with partial support of Blauvelt through this grant. In all three years of field and follow-up laboratory work, undergraduate students from Buffalo and elsewhere participated (eight undergraduate students altogether).

- *References.* The publications that have resulted from the grant (in whole or in part) are the following:

Martinez-Hackert, B. and Bursik, M., 1999, Observations of gullywash during the Summer, 1999, monsoon, San Francisco Volcanic Field, AZ, AGU Fall Meeting Abstracts, Eos, December.

Bursik, M. and Reid, J., 1999, Reconnaissance of lahar deposits, Glass Creek and Owens River, California, AGU Fall Meeting Abstracts, Eos, December.

Pietraczek, J., Deming, J., Valley, P. and Bursik, M., 1999, Preliminary study of uplift and eruption of Paoha Island, Mono Lake, CA, AGU Fall Meeting Abstracts, Eos, December.

Martinez-Hackert, B., Bursik, M. and Hooper, D., 1999, Erosion following fire on cinder cones in the San Francisco Volcanic Field, AZ, Geol. Soc. Amer., Abstracts with

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- Martinez-Battori, B., Bursik, M. and Hooper, D.M., 1998, Results of short-term degradational processes on cinder cone hillslopes in a semiarid climate, AGU Fall Meeting Abstracts, Eos, December.
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- Bursik, M., Delgado, H., Gonzalez-Huesca, A., 1999 in revision, A smoothed-particle hydrodynamic automaton of landscape modification: theory, tests and an example, Geomorphology
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- Wieczorek, G.F., Snyder, J.B., Waite, R.B., Morrissey, M., Uhrhammer, R., Harp, E.L., Norris, R.D., Bursik, M.I., and Finewood, L.G., 2000, The unusual July 10, 1996, rock fall at Happy Isles, Yosemite National Park, California, Bulletin of the Geological Society of America, 112, 75-85.
- Please also see the web page <http://wings.buffalo.edu/geology/mib/flv/>, which contains recent results from our analyses of the Long Valley-White Mountains TOPSAR DEM.